Erasmus MC
University Medical Center Rotterdam

Daniel den Hoed
Cancer Center

Non-coplanar multi-criterial beam angle optimization with iCycle

Sebastiaan Breedveld

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iCycle

Optimization techniques:

- IMRT
- multi-criteria
- beam angle optimization

Currently, only 1 and 2-combinations are used:

- IMRT
- (conformal) multi-criteria
- (conformal) beam angle optimization
- multi-criterial IMRT
- IMRT beam angle optimization

Objective was to design a:

Multi-criterial non-coplanar beam angle optimization with IMRT

A priori multi-criteria

- Uses a wish-list
- Gives a solution which is feasible, closest to requested
- Wish-list is a guide for the beam angle optimization

The equivalence of multi-criteria methods for radiotherapy plan optimization 2009, Breedveld, Storchi and Heijmen, PMB 54

Wish-list

- Uses a wish-list
- Gives a solution which is feasible, closest to requested

Constraints

Nr	Volume	Type	Limit
1	PTV Boost	maximum	53.5 Gy
2	PTV	maximum	53.5 Gy
3	Nerves†	maximum	55 Gy
4	Unspecified Tissue	maximum	53.5 Gy

Objectives

Priority	Volume	Type	Goal	Parameters
1	PTV Boost	minimize LTCP	1	$\alpha = 0.75$, Sufficient $= 0.5$
2	PTV	minimize LTCP	1	$\alpha = 0.75$, Sufficient $= 0.5$
3	Eye (L)	minimize EUD	15	$a = 15$
4	Eye (R)	minimize EUD	15	$a = 15$
5	Parotid (L)	minimize mean	26	
6	Parotid (R)	minimize mean	26	

† Brainstem, Cord, Sella, Optic Chiasm, Optical Nerves

Wish-list

Objectives

Priority	Volume	Type	Goal
1	PTV Boost	minimize LTCP	1
2	PTV	minimize LTCP	1
3	Eye (L)	minimize EUD	15
4	Eye (R)	minimize EUD	15
5	Parotid (L)	minimize mean	26
6	Parotid (R)	minimize mean	26

Iteration	Volume	Result	New constraint
1st phase 1	PTV Boost	0.10	1.00
2	PTV	0.01	1.00
3	Eye (L)	20.11	20.71
4	Eye (R)	18.12	18.66
5	Parotid (L)	19.18	26.00
6	Parotid (R)	19.77	26.00
2nd phase 7	PTV Boost	0.97	1.00
8	PTV	0.01	0.50
9	Parotid (L)	20.95	21.58
10	Parotid (R)	24.33	24.33

A priori multi-criteria

Objectives

Priority	Volume	Type	Goal
1	PTV Boost	minimize LTCP	1
2	PTV	minimize LTCP	1
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	10	Parotid (R)	24.33	24.33

This is the best you can get!

iCycle

iCycle sequentially adds beams

Beam selection phase:

- each beam candidate is optimized, along with already selected beams
- target dose is maximized, keeping OARs constrained
- best beam is selected and added to the beam set

Multi-criteria phase:

- a multi-criteria optimization is done
- new constraints for the OARs are set based on the MC result

iCycle Movie

iCycle

All the good things from the multi-criteria method propagate to the beam angle optimization:

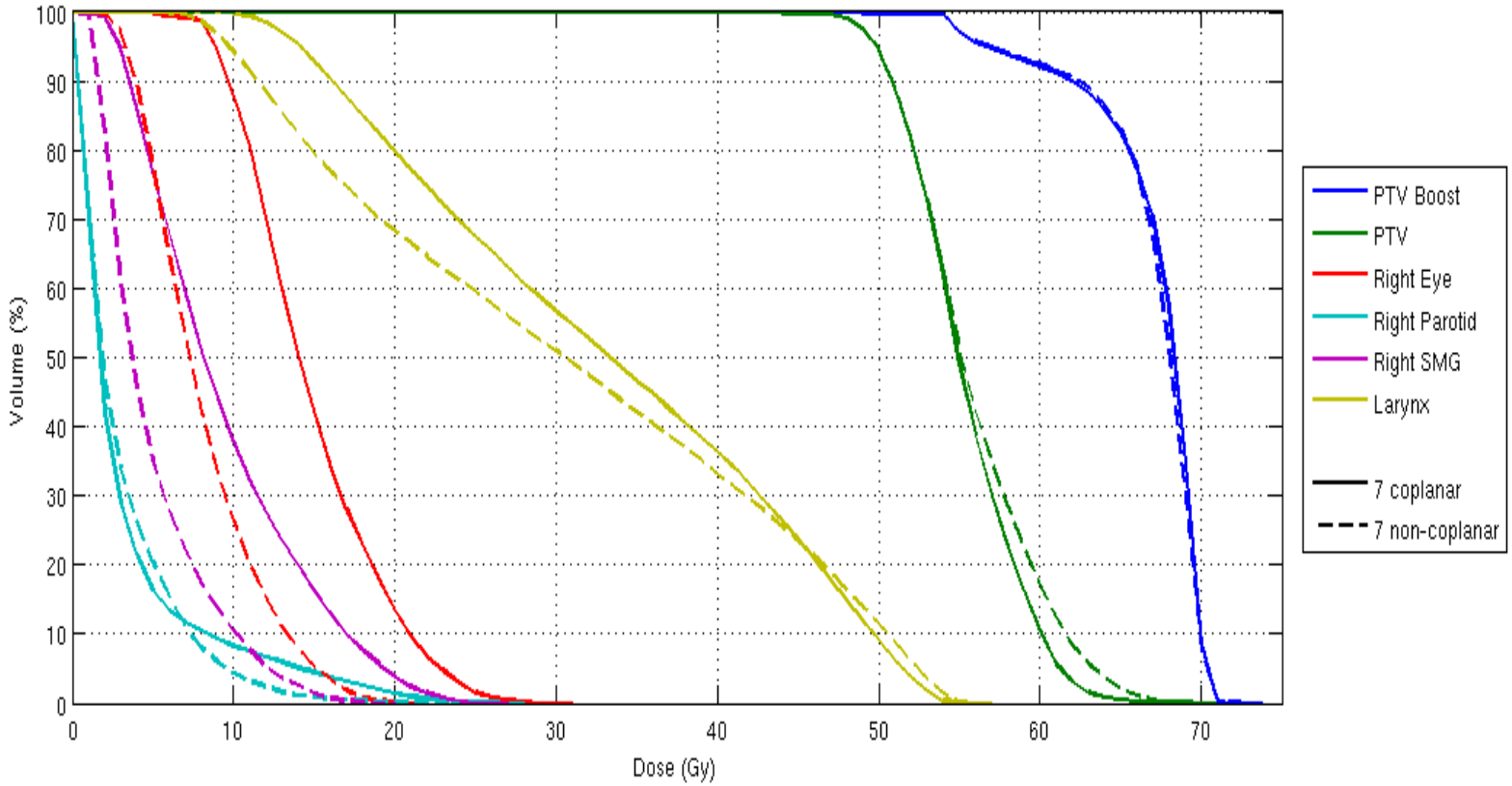
- A beam set is returned which is best able to spare the highest prioritized structures
- Automatic removal of structures which cannot be spared
- Result of the beam angle optimization is directly Pareto-optimal

As a result of the sequential beam addition:

- No need to specify a maximum number of beams
- Optimal number of beams is selected afterwards

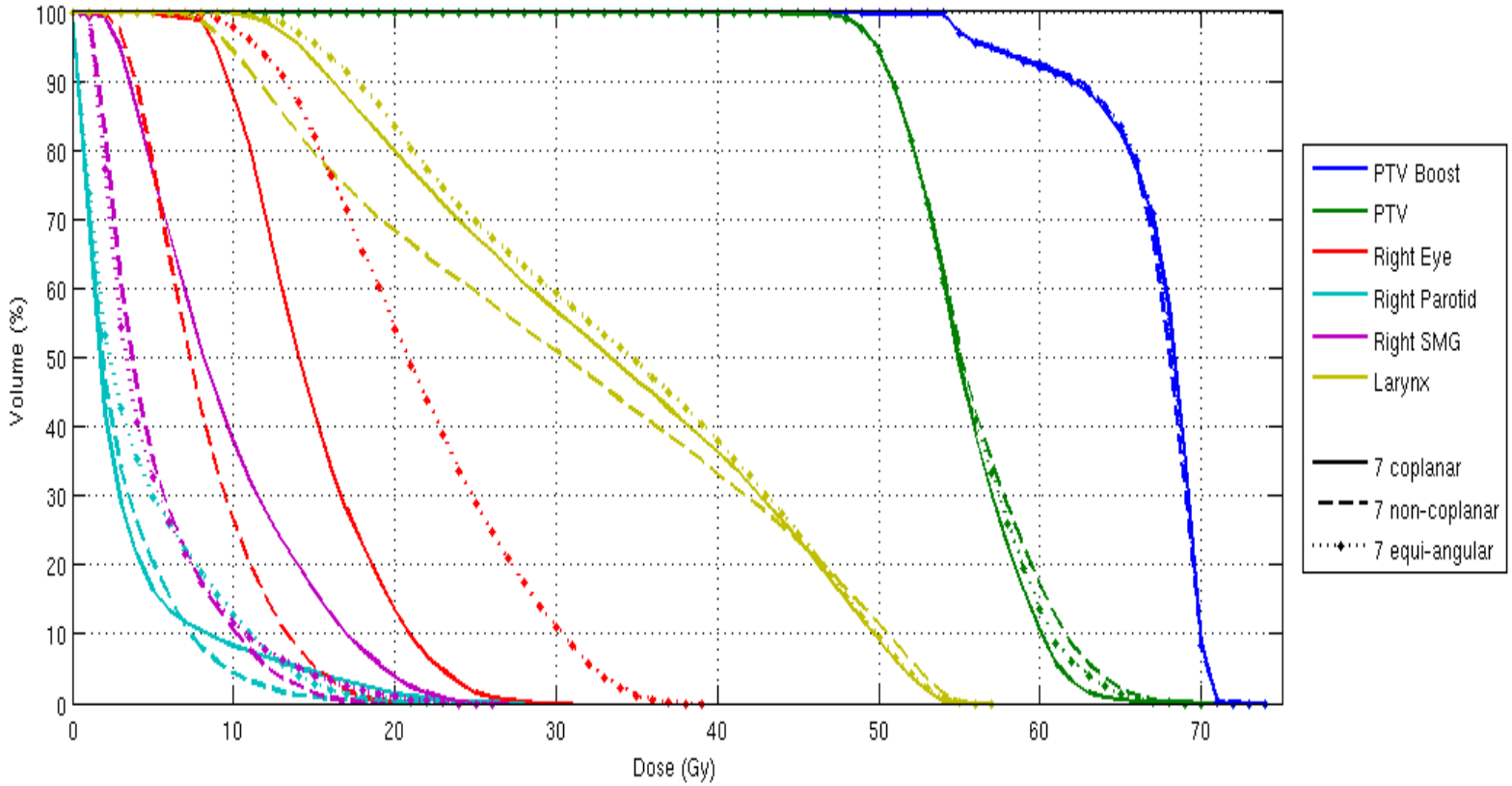
iCycle: head-and-neck 1

Compare coplanar and non-coplanar setup with 7 beams



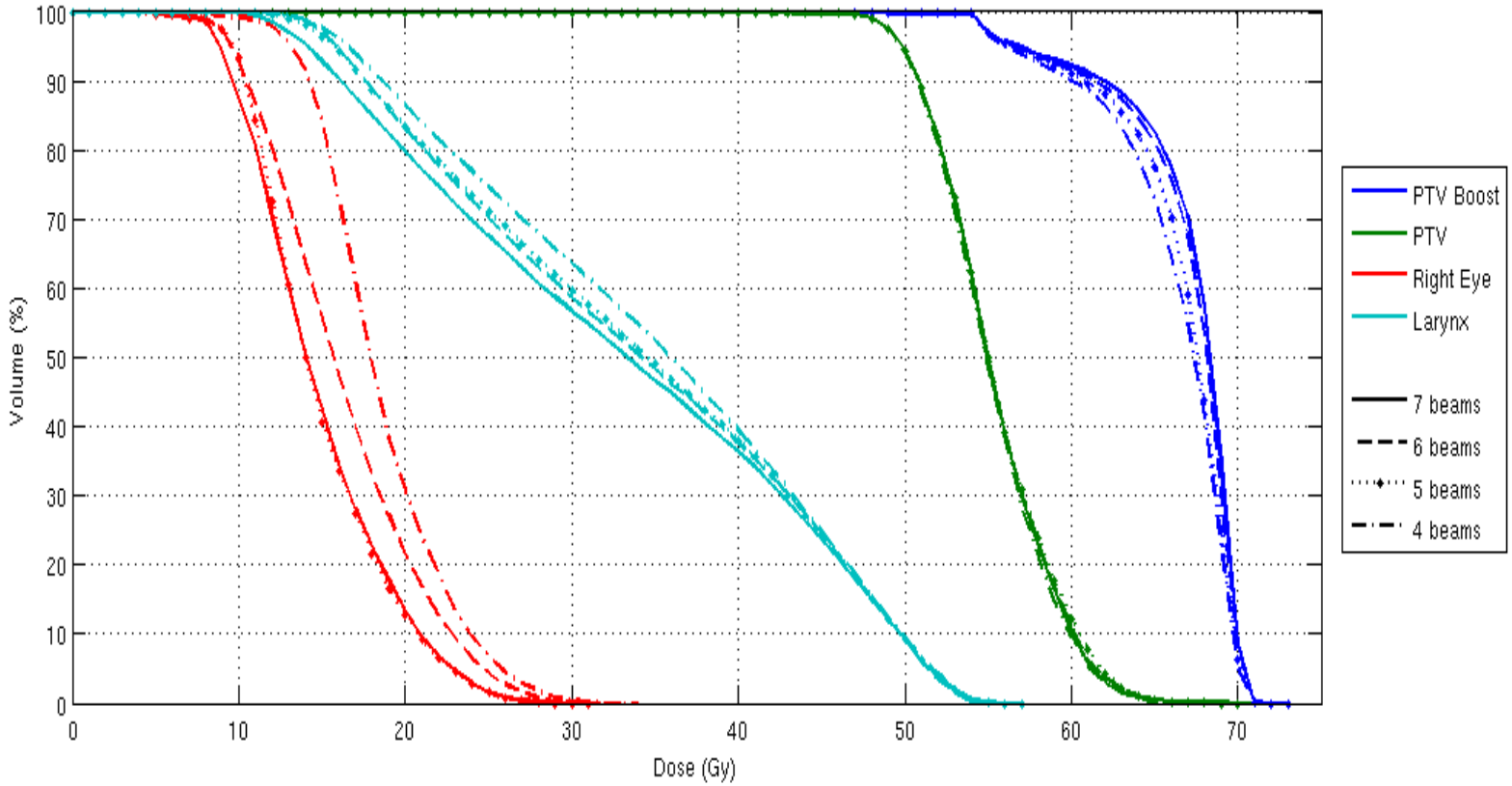
iCycle: head-and-neck 1

Compare coplanar and non-coplanar setup with 7 beams with 7 equi-angular spaced beams



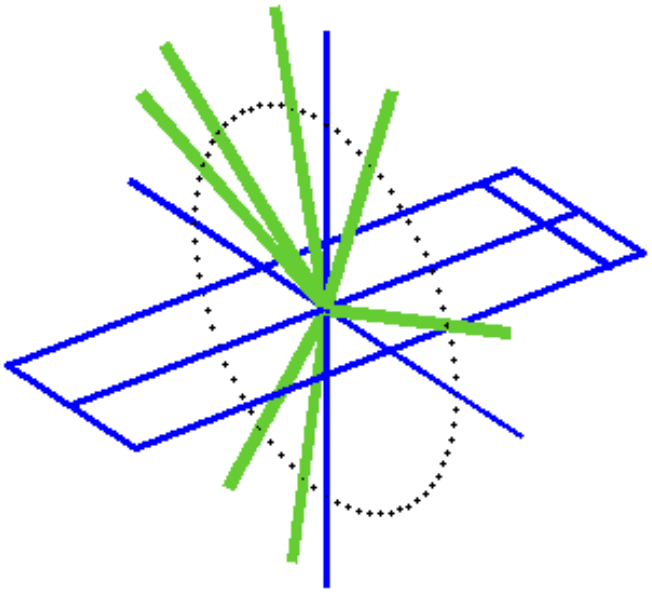
iCycle: head-and-neck 1

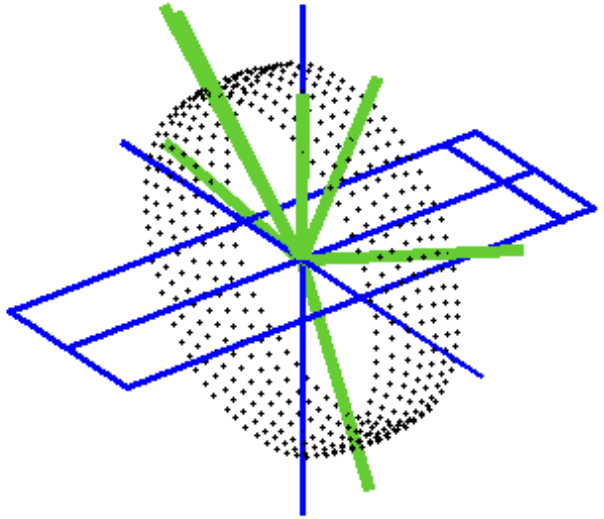
Improvement after adding more beams



iCycle: head-and-neck 1

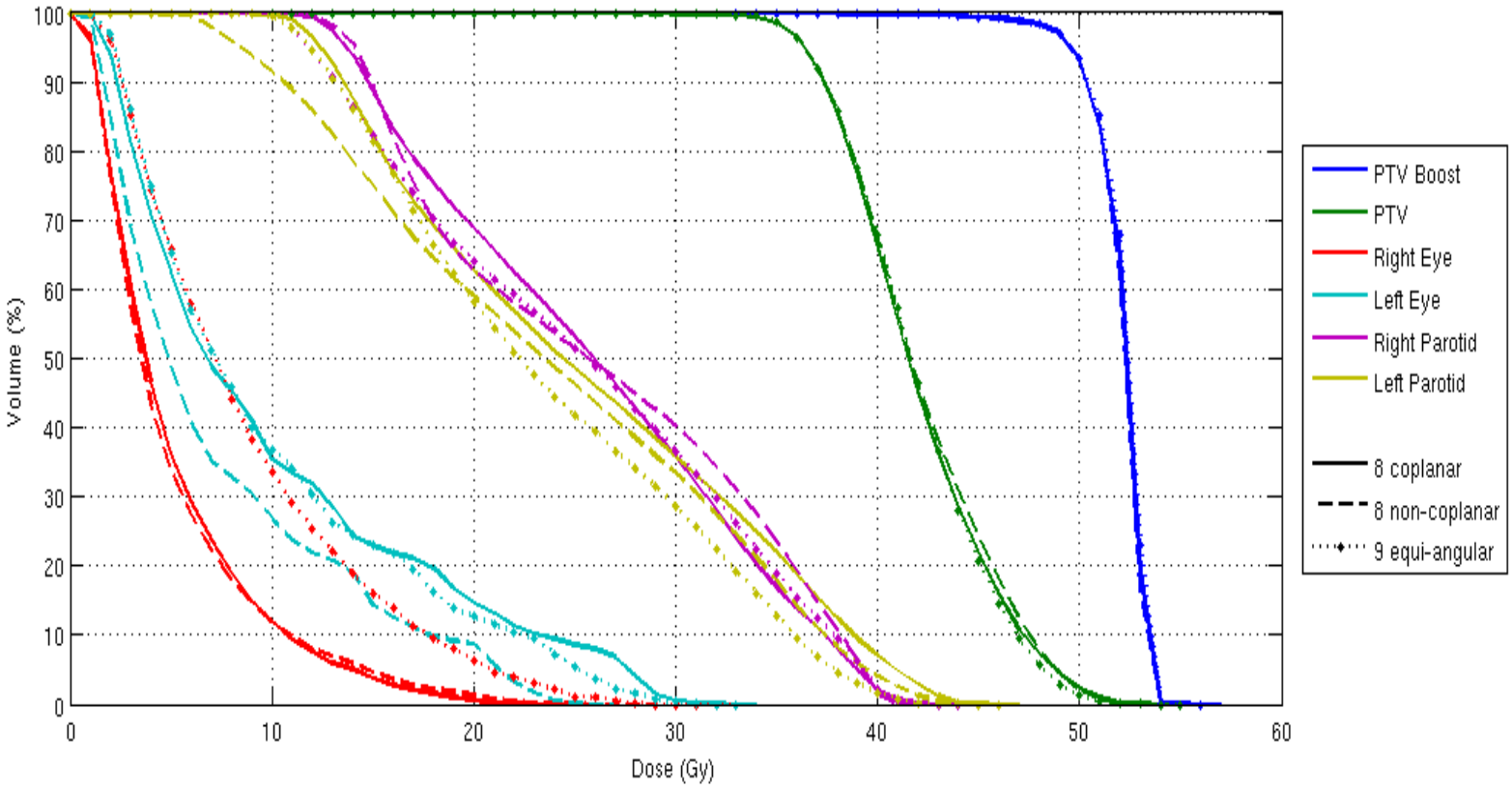
Selected beam orientations





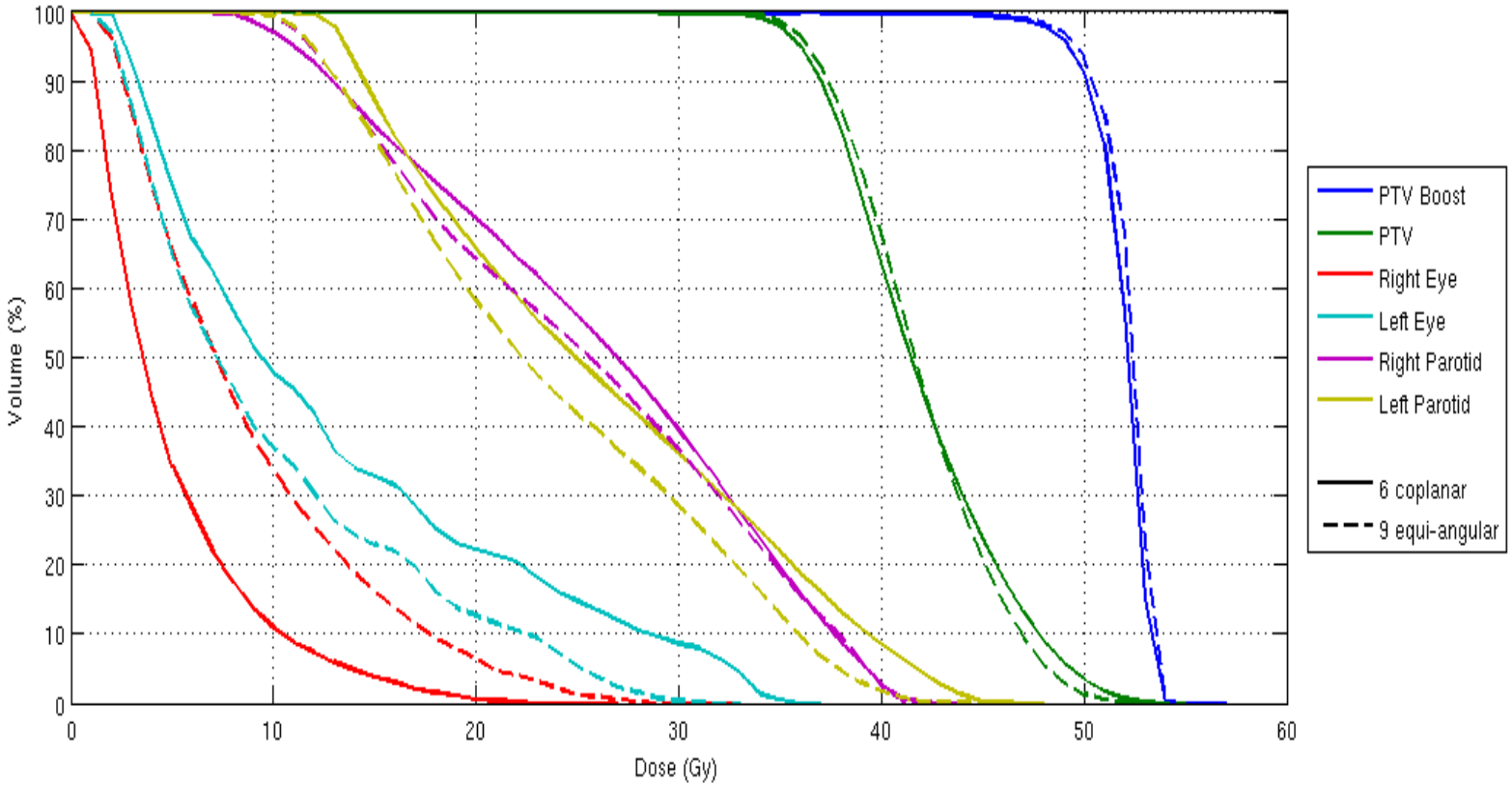
iCycle: head-and-neck 2

Compare coplanar and non-coplanar setup with 8 beams with 9 equi-angular spaced beams



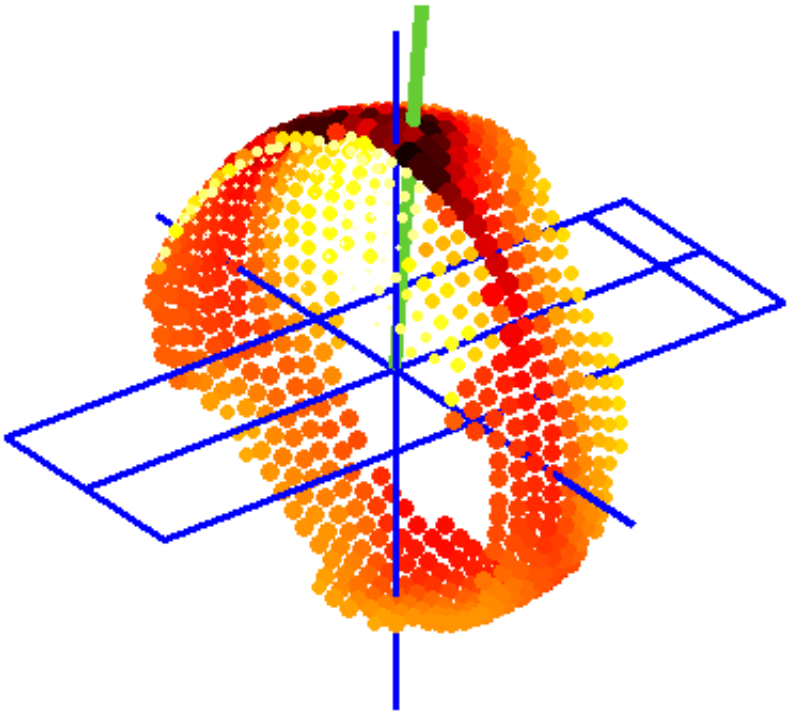
iCycle: head-and-neck 2

Compare coplanar 6 beams with 9 equi-angular spaced beams



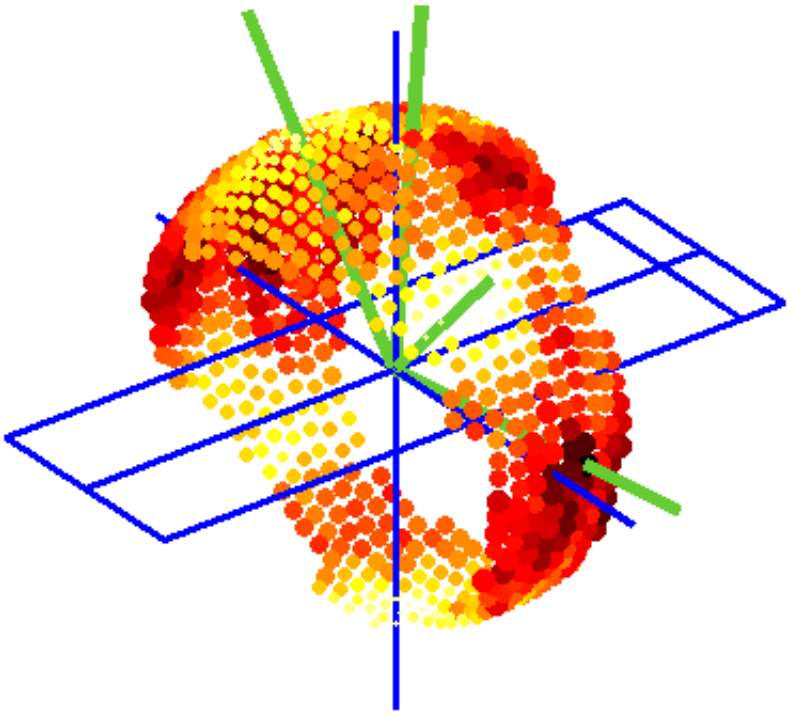
iCycle: head-and-neck 2

Beam selection: 1st beam



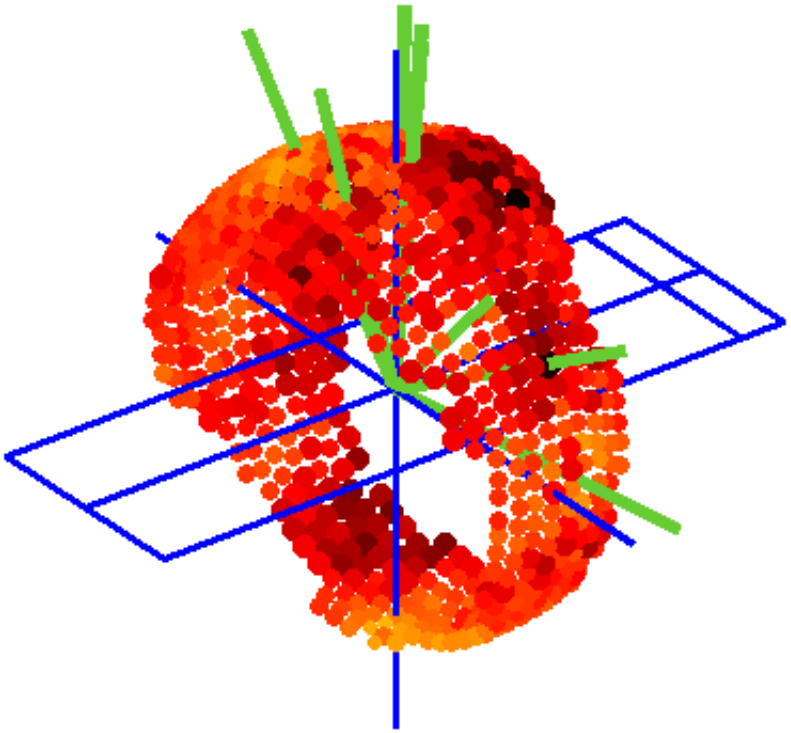
iCycle: head-and-neck 2

Beam selection: 4th beam



iCycle: head-and-neck 2

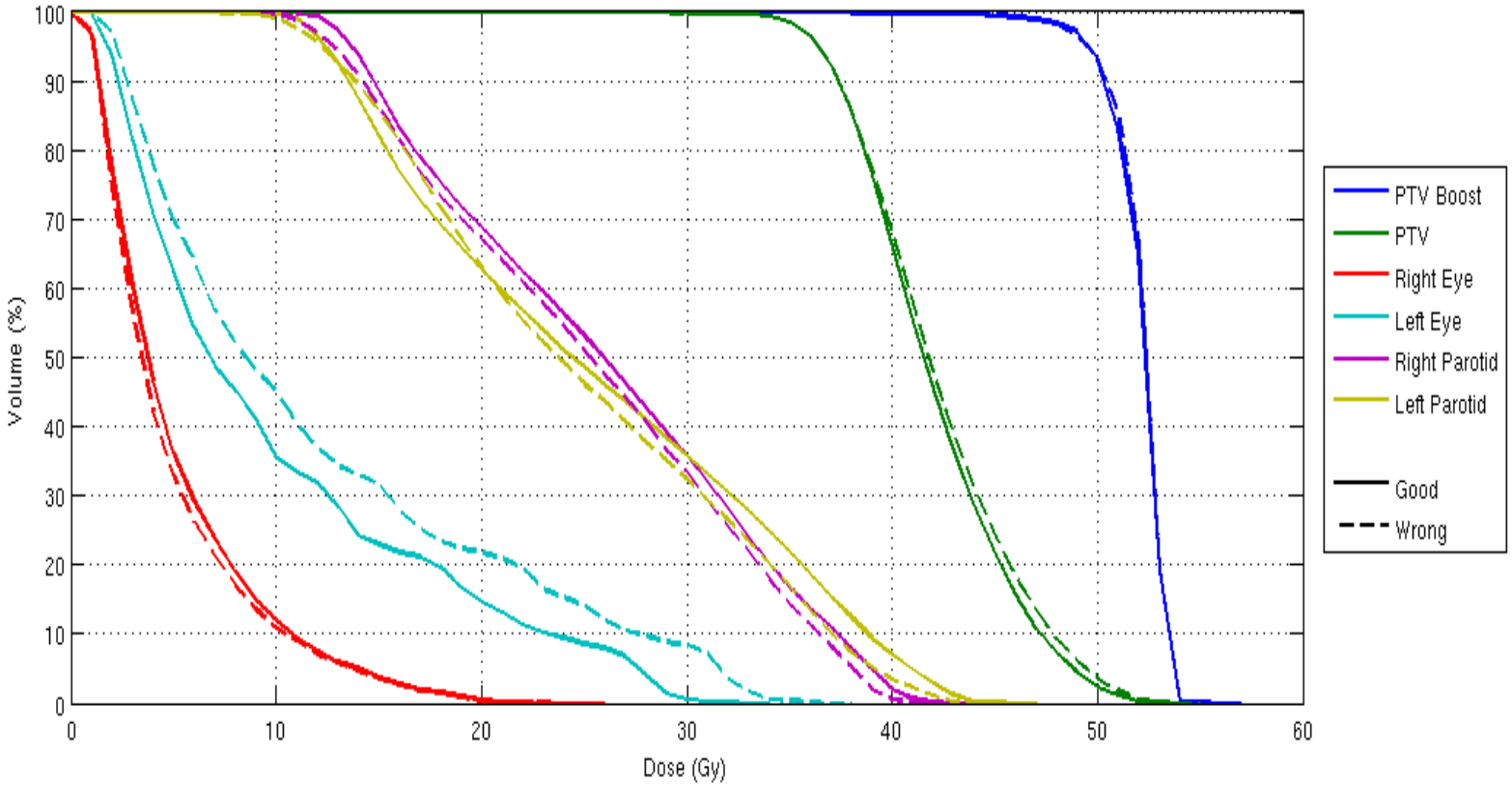
Beam selection: 8th beam



iCycle: influence of priorities

Use angles from a 'left-prioritized' list on 'right-prioritized' MC optimization.

Compare with right-prioritized angles.



Conclusions

iCycle performs very well

shows significant improvement wrt. equi-angular beam setup

shows improvement for non-coplanar angles

easy to program with the wish-list, can use templates

no need to specify number of desired beams